

Identifying the economic impact from ULEV uptake

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Executive Summary

Aims

The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 gives Scotland a target of net zero by 2045. The transport sector presents the biggest challenge to decarbonisation, with emissions increasing each year since 2010. In 2016, transport (including aviation and shipping) contributed 37% of Scotland's total greenhouse gas emissions. However, Scotland has shown strong ambition in this area: the Scottish Government has pledged to remove the need for new petrol and diesel vehicles by 2032.

Transport Scotland, the national agency tasked with delivering this pledge, is focusing on three outcomes:

- positioning Scotland at the forefront of growth in the ultra-low emission vehicles (ULEVs) market;
- achieving a fair distribution of investment costs benefitting all consumers; and
- generating business benefits from new markets and technology.

Transport Scotland is aware that increasing ULEVs will have both positive and negative consequences. To help it develop interventions, this report has: identified the economic impacts; developed a detailed framework to assess them; and used the outcomes to highlight the implications for policies to smooth the transition to ULEVs. The framework has broken down the impacts into five main areas:

¹ This research completed in March 2020 but was published in January 2021, after the Climate Change Plan update was published .

- vehicle and infrastructure manufacturing;
- consumer expenditure;
- CO₂ emissions and air quality;
- fuel supply; and
- tax revenues.

We have implemented two scenarios in the framework, reflecting varying deployment of the differently powered vehicles as a share of total sales. The 'impact' of a scenario is equal to the difference between the scenario and the baseline. The baseline assumes no change in the share of sales of the different vehicles from the most recent Scottish transport statistics.

For this report, we have concentrated on the scenario (Scenario 3 in the framework), prepared by Element Energy for Transport Scotland, which comes closest to meeting Scotland's climate change targets. This scenario achieves the 2040 and 2045 targets, and almost meets the 2030 target.

Findings

In this scenario, the overall economic impacts are positive over the long term:

- Gross Value Added² (GVA) is higher in this scenario than in the baseline (in which ULEV deployment remains in proportion with that which occurred in 2018 in Scotland) across all years from 2027 to 2050.
- In the short term, GVA is lower for two main reasons: higher investment costs and the high price of ULEVs (relative to internal combustion engine vehicles (ICEs)) which reduces consumer spending in other areas.
- Total economy-wide employment (on a full-time equivalent basis) is higher by 2043 reaching a net gain by of 2,700 jobs by 2050 but is below the baseline for most of the period.
- ICE maintenance jobs are most at risk from the transition to ULEVs. The framework shows that more than 10,000 ICE maintenance jobs could be at risk by 2050 as ULEV powertrain have different maintenance requirements. The jobs at risk are likely to be distributed widely across Scotland, reflecting the geographic distribution of maintenance garages.
- The oil and gas industry also faces significant job losses. We estimate around 4,000 of the 30,000 people directly employed in the oil and gas sector in Scotland³ are at risk of losing their jobs. This will have a particularly acute impact in Aberdeenshire where most of these jobs are located.
- Up to a further 2,500 job losses could be lost at refuelling stations, partly because many ULEVs will often be charged from home.

² Gross Value Added (GVA) is a measure of output of an economy; specifically, it measures the difference between the cost of inputs and the price of outputs, i.e. the 'value added' during the production process beyond the cost of materials.

³ Oil & Gas UK. (2018). Workforce Report 2018. Retrieved from <https://oilandgasuk.co.uk/wp-content/uploads/2019/03/OGUK-Workforce-Report-2018.pdf>

There is potential for the creation of around 3,000 new jobs in the production of ULEVs, drawing on Scotland's extensive expertise in electrical engineering. In particular, there appears to be an opportunity in developing low-emission heavy-duty vehicles (HDVs). Our analysis suggests a further 500 jobs could be created at companies installing and operating ULEV infrastructure.

The scenario suggests substantial environmental benefits:

- CO₂ emissions are reduced by 113m tonnes or 49% cumulatively over 2020-2050, from 232m tonnes to 119m. These can be monetised⁴ to show a total annual net benefit of £1.076bn (not discounted) in 2050.
- Improvements to air quality from the annual reduction in tailpipe emissions of NO_x and PM2.5s are estimated to reduce annual damages to human health by the equivalent of £335m⁵ in 2050 alone.

Implications for policy

Two priority areas require the most urgent action, based on the scale of economic activity likely to be displaced in the transition:

- ICE maintenance sector: the transition to ULEVs can represent an opportunity for these businesses, but they will require support to retrain their employees and refocus their businesses towards the services and parts required for ULEVs. Those that lose their jobs will need support to find employment elsewhere in the economy. Action should also be taken to ensure new entrants to the sector receive training in ULEV maintenance.
- Oil and gas sector: the transition offers opportunities in adjacent industries for those losing their jobs. The government could support further development of a zero-carbon fuels industry, including renewable offshore resources and the nascent carbon capture, utilisation and storage (CCUS) segment.

More broadly, the Scottish Government should consider exploring:

- a replacement for fuel duty to discourage additional use of motorised transport as a result of the lower cost to consumers of transport using electric vehicles;
- measures to support the operation of firms manufacturing or retrofitting ULEVs;
- financial measures to support refuelling stations important for rural communities; and
- standards for refuelling stations and a plan to deliver infrastructure to support ULEVs into the future.

To develop the framework, we reviewed relevant literature, including existing studies which have quantified the socioeconomic impacts of the transition to EVs. The specific data sources and assumptions used to construct the framework can be found in the detailed methodology in Appendix B, and data sources in Appendix C.

⁴ Based on the Social Price of Carbon recommended by HM Treasury for use in assessing CO₂ emissions in non-traded sectors (i.e. those outside of the scope of the EU Emissions Trading Scheme)

⁵ Based on the health damage coefficients calculated by Ricardo for DEFRA

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1 Introduction

1.1 Policy context

Scotland has historically shown strong political commitment to tackling climate change, as evidenced by the Climate Change (Scotland) Act 2009 which set a target to reduce emissions by 80% between 1990 and 2050. This commitment has been taken further by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019. This tightens the target to net zero by 2045, five years ahead of the UK Government's commitment to achieve net zero emissions by 2050, and endows Scotland with among the most stringent climate targets in the world.

Scotland's transport sector presents the biggest challenge to decarbonisation, with emissions increasing each year since 2010. In 2016, transport (including aviation and shipping) contributed 37% of Scotland's total greenhouse gas emissions. Element Energy's 2016 carbon budget modelling study for Transport Scotland found that cars and vans contribute just over half of these emissions, but they also show the strongest potential for emissions reduction⁶.

Scotland has, consequently, shown strong ambition in this area. While the UK Government plans to end the sale of new petrol and diesel cars and vans by 2040, the Scottish Government has pledged to remove the need for these vehicles eight years earlier, by 2032.

1.2 Challenges

Meeting this ambitious goal will require a rapid shift in purchasing behaviour among car and van buyers. At the end of 2018, ultra-low emission vehicles (ULEVs)⁷, such as battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs) and hydrogen fuel cell electric vehicles (FCEVs), accounted for 0.42% and 0.16% of Scotland's car and van stock respectively⁸. The share of such vehicles in Scotland is slightly below the UK average: across the UK as a whole, 0.57% of cars are ULEVs, and 0.19% of vans.

Uptake is expected to increase as ULEV prices fall, refuelling infrastructure becomes more widespread, range increases, and choice of models grows. However, modelling of uptake, using Element Energy's proprietary ECCo choice model, suggests that without further policy interventions, ULEVs will account for only 35% of new car sales and 28% of new van sales in Great Britain in 2032. Thus, driving the transition to higher uptake will likely require further government intervention. Scotland has already shown an appetite to provide this support, for example, the 2017 Programme for Government's commitments to introduce Low Emission Zones in Scotland's four biggest cities by 2020 (followed by all Air Quality Management Areas by 2023) and to expand the charging infrastructure across the country between now and 2022.

Niche HDV manufacturing may be another opportunity for Scottish businesses.

1.3 Objectives of the study

Understanding the potential economic impacts, both positive and negative, is critical to achieving a successful transition to full ULEV adoption. This can help ensure the costs and benefits of the transition are distributed fairly across all consumers, and that the potential opportunities for Scottish businesses are identified and capitalised upon. As stated in Scotland's Energy Strategy, this could include increasing participation in the UK's vehicle supply chain or developing niche transport applications in Scotland's rural and island

⁶ Element Energy for Transport Scotland (2016) Greenhouse gas emissions reduction potential in the Scottish transport sector from recent advances in transport fuels and fuel technologies.

⁷ Defined as those with an NEDC type-approval emissions value of 75 gCO₂/km or less.

⁸ UK Department for Transport vehicle statistics: Table VEH0130 and Table VEH0104.

communities. Niche HDV manufacturing may be another opportunity for Scottish businesses. To this end, this study has:

- identified possible economic impacts of increasing ULEV uptake in Scotland;
- developed a detailed evaluation framework to assess the size of each impact; and
- used the outcomes of the framework to highlight implications for policy to facilitate a smoother ULEV transition.

1.4 Structure of the report

Chapter 2 explains how the evaluation framework operates, including the main outputs. In Chapter 3, we outline the scenarios that have been evaluated using the framework, reflecting work carried out by Element Energy for Transport Scotland. Chapter 4 discusses the economic and environmental findings once the framework is applied to these scenarios. Chapter 5 discusses the policy implications of the impact of the transition to ULEVs. Chapter 6 sets out conclusions from the work. The appendices then contain further detailed information, including a user guide, which explains how to use the framework, a detailed methodology for the framework, and a list of data sources.

2 Overview of ULEV Framework

The ULEV framework is an Excel-based tool which includes a representation of vehicle stock, fuel demand and emissions in Scotland to assess the impact on the economy. The impact on the economy can be broken down into five main impact areas:

- vehicle and infrastructure manufacturing;
- consumer expenditure;
- CO₂ emissions and air quality;
- fuel supply; and
- tax revenues.

The ‘impact’ of a scenario is equal to the difference between the scenario and the baseline. The baseline assumes no change in the share of sales of the differently powered vehicles from the most recent Scottish transport statistics. There are two available scenarios in the ULEV framework which allow the user to design and implement two distinct futures of varying deployment of powertrains as a share of total sales.

2.1 Framework structure

The evaluation framework comprises four distinct stages:

- scenario inputs (share of sales);
- supporting input and assumptions;
- pillar calculations⁹; and
- results in impact areas.

Figure 1 below shows how the different stages of the framework interact to give the outcomes for the impact areas. Each calculation is explained in detail in Appendix B.

⁹ Pillar calculations, which are outlined in the diagram on the next page, are key intermediate calculations upon which much of the derivation of the final economic impacts are based. They include indicators such as the vehicle stock by age, the fuel efficiency of the fleet, fuel demand, emissions and infrastructure costs, and are themselves the combination of a number of inputs and assumptions. We highlight them in our framework due to the influence they have on the final impacts.

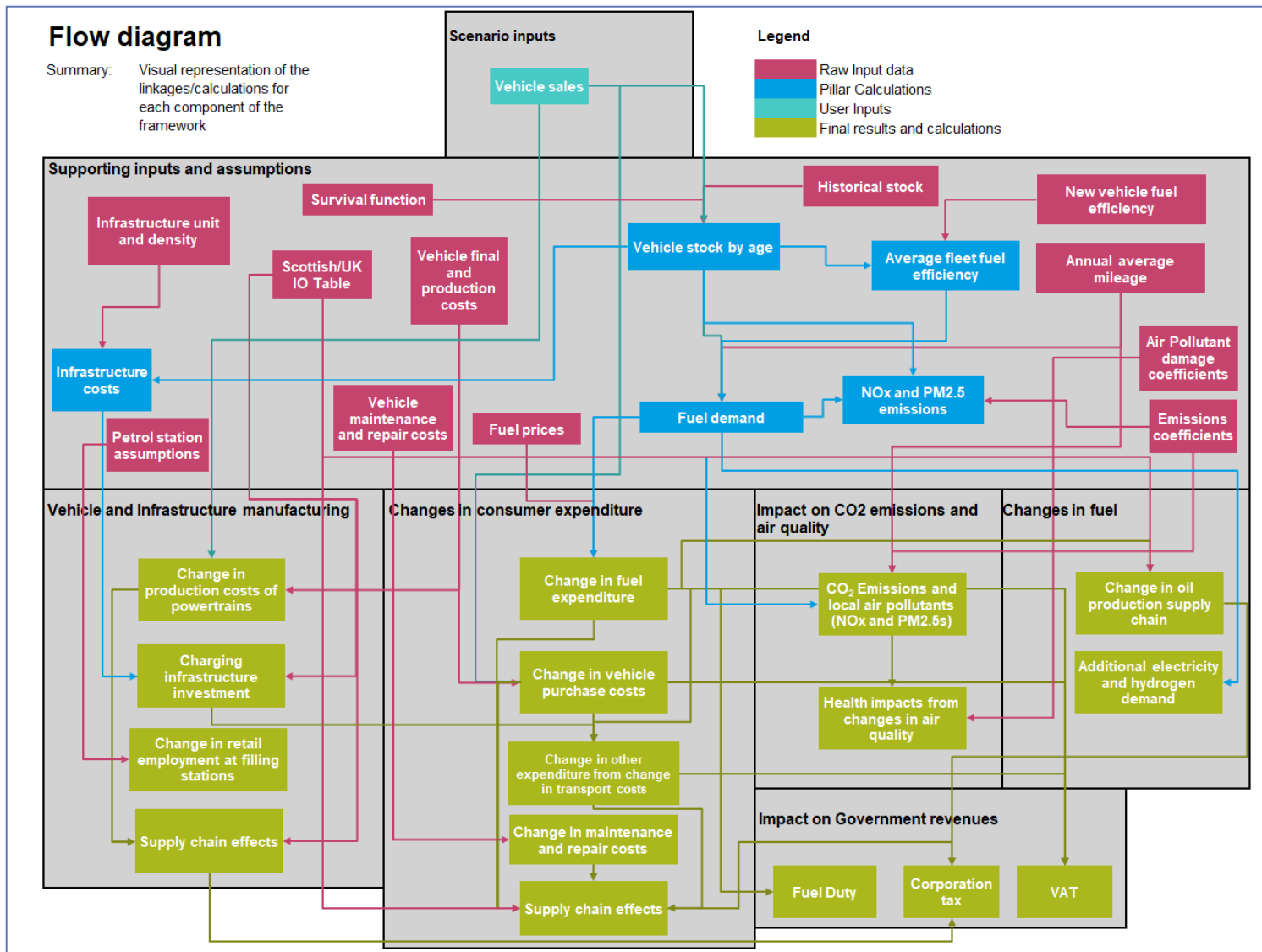


Figure 1: ULEV framework flow diagram

This section describes in detail the main outputs of the framework in the different impact areas. The supply chain effects are described first because they are a common calculation in the results of the Vehicle and infrastructure and Consumer expenditure impact areas. For more detail on the methodology please see Appendix B.

2.1.1 Supply chain effects

The framework calculates supply chain effects using either Type I or Type II Gross Value Added (GVA) Effects and Type I or Type II Employment Effects from Scottish Input-output supply and use tables. Type I multipliers capture the direct (change in output of an industry where the change occurred) and the indirect (change in industries along the supply chain from the change in the initial industry) effects. In addition to the effects captured in Type I, Type II also include induced effects (change in wages from direct and indirect supply chain effects).

The Scottish Government provides two categories of multipliers: the standard multiplier and the effect multipliers. The effect multipliers are used since they express the direct and indirect and induced change in GVA (or employment) resulting from a change in output, rather than an initial change in GVA (or employment) as would be the case for standard multipliers. GVA is measured in millions £ (£m) in 2015 prices and employment is measured in numbers of Full-Time Equivalents (FTE).

2.1.2 Vehicle and infrastructure

In this section, the framework calculates changes in vehicle production and the additional infrastructure needed for rollout of ULEVs. The focus for vehicles is the net change in powertrain production, comparing the loss from traditional internal combustion engine (ICE) manufacturing to the gain in ULEV advanced powertrain manufacturing. New infrastructure is required to meet the demands of the ULEV fleet: different sizes of electric chargers and HRS, and the loss of petrol stations, are considered here. For supply chain effects, we look at both the change in vehicle powertrain production and the deployment of charging and refuelling infrastructure.

2.1.3 Consumer expenditure

This area focuses on the impact of ULEV uptake on consumer expenditure. It evaluates the impact of the change in fuel expenditure, vehicle purchases, repaying infrastructure costs and changes in maintenance costs.

In terms of direct supply chain effects, production and distribution of fossil fuels for ICEs falls while the supply of electricity and hydrogen increases. The purchase of vehicles also has other industry impacts which are not included in the vehicles and infrastructure manufacturing part of the framework. Due to the difference in margins between ICEs and ULEVs, dealerships' revenue will change.

Manufacturing of vehicle bodies is also considered. However, the activity in this sector does not vary according to how the vehicle is powered because it is assumed the same industry will make ULEV bodies. It would only change if the total number of vehicle sales changes between the baseline and the scenarios: the assumption of constant absolute sales mean there is no change in production. Maintenance and repair of vehicles is impacted by the ULEV transition, however: ULEVs cost less to repair and maintain because they have fewer moving parts than ICE vehicles.

As well as the changes to the supply chain, lower net transport costs lead to increases in consumers' disposable income which is spent elsewhere in the economy.

2.1.4 Impact on CO₂ emission and air quality

In this section the impact on air quality is calculated through changes in emissions of CO₂ (kt), NO_x (tNO₂-eq) and PM_{2.5} (t) resulting from a phase out of ICEs. Note that only the change in tailpipe emissions is considered here, not emissions from energy production or industry. The framework also calculates the change in damage costs (£m) based on damage coefficients from the Air Quality damage cost update for Defra by Ricardo (2019) which capture the change in health impacts caused by NO_x and PM_{2.5} pollutants.

2.1.5 Fuel supply

The impact on oil, electricity and hydrogen fuel supply is captured here. The fuel supply (TJ) of electricity and hydrogen is simply the addition of the demand for fuel from the deployment of ULEVs. However, further consideration is taken of the change in demand for fossil fuel, whereby the change in oil supply (£m), both domestic and imported, is calculated.

2.1.6 Government revenue

The final section calculates the change in government revenue in three areas: fuel duty, VAT and corporation tax (all measured in £m). Changes in fuel duty arise from the reduction in demand for middle distillates as demand switches to electricity and hydrogen. Changes in VAT come from changes in fuel, vehicle and other consumer expenditure purchases. Corporation tax changes are calculated based on the change in profit in the supply chain of the transition (e.g. vehicle and infrastructure GVA effect etc.).

3 Scenario Description

The framework analyses the economic impacts of ULEV uptake; the final outcomes are a direct result of the deployment scenarios. In this study, we make use of ULEV projections created by Element Energy for Transport Scotland in a separate piece of work examining how Scotland can meet its climate change targets. From that analysis, two of the scenarios are of interest to this work. These are “Scenario 2” and “Scenario 3”, which both meet Scotland’s 2040 and 2045 targets, but fall short of meeting Scotland’s 2030 target. Scenario 3 comes closest to meeting all targets. The scenarios are described in detail below.

3.1 Scenario 2

This scenario combines a rapid technology shift, from polluting to non-polluting vehicles, with major behavioural change. In this scenario, zero-emission vehicles are introduced as quickly as is considered possible given the constraints in global supply. This results in an end to the sale of polluting buses and coaches in 2025, cars and vans in 2030 and trucks in 2035. As a result, all polluting vehicles have naturally left the fleet (i.e. without introducing schemes to encourage the early scrappage of such vehicles) by 2045, in order to be consistent with the net zero target for this year. This scenario assumes no restrictions on the mobility of people and goods, with as many person kilometres and freight tonne kilometres completed as in the business-as-usual case.

However, modal shift to more efficient modes of transport (e.g. people moving from single-occupancy cars to well-utilised buses) is employed to reduce vehicle kilometres and, therefore, emissions. The key modal shift behaviour changes included in this scenario are a major change in the way urban people travel, with many short trips switching from cars to walking and cycling, and many longer trips moving from cars to public transport. Similarly, in the freight sector there is a shift from trucks to rail for the longest trips, especially those between Scotland and England.

3.2 Scenario 3

This scenario captures all the technology and modal shift changes introduced in Scenario 2, but takes them further by assuming that behaviour changes include some destination switching (better access to goods and services results in average trip lengths becoming shorter) and trip displacement (options such as working from home and attending business meetings through teleconferencing allow some trips to be avoided completely). These result in an absolute reduction in the number of person kilometres and freight tonne kilometres required in Scotland.

4 Framework Results

4.1 Introduction

For the outcomes presented below, we assessed the economic impact of Scenario 3 relative to a baseline. This baseline assumes no change in the share of sales of powertrains from the most recent annual Scottish transport statistics. However, total sales, vehicle stock and mileage in the baseline are adjusted to be consistent with the other changes to the Scottish fleet in the scenario to reduce transport demand. In effect, we remove the additional impact of a reduction in overall transport demand (the key difference between Scenario 2 and Scenario 3, as outlined in the previous chapter). This is to ensure we are measuring *just* the economic impact of the deployment of ULEVs, and not the changes associated with other changes to the Scottish vehicle fleet (e.g. a smaller fleet which would have its own economic impacts).

4.2 Headline findings

4.2.1 Economic results

The key findings from the analysis are:

- Overall, the economic impacts are positive over the long term, with GVA higher across all years from 2027 to 2050 in Scenario 3 compared to baseline. GVA is initially lower because of the investment costs and because the high price of ULEVs reduces consumer spending elsewhere in the economy. Employment (on an FTE basis) remains below baseline for most of the period, although by 2043 the impacts become positive, as a result of the shifts in economic activity.
- There are substantial environmental benefits: CO₂ emissions are reduced by 113m tonnes or 49% cumulatively over 2020-2050, from 232m tonnes to 119m, and the improvements to air quality from the reduction in emissions of NO_x and PM2.5s are estimated to reduce damage to human health by the equivalent of £335m in 2050 alone.

The economic impacts are summarised below in Figure 2. There is a sustained positive impact on GVA, as the shift to ULEVs leads to a reduction in demand for conventional fossil fuels (some of which is extracted/refined in Scotland, but much of which is not) and an increase in demand for electricity (which is all generated within Scotland). In addition, more of the ULEV vehicle production value is captured in Scotland compared to ICEs. In the long term, the lower overall cost of transportation leaves money in the pockets of Scottish consumers for spending on other goods and services (of which some are imported, but a substantial proportion is spent within the Scottish economy¹⁰).

¹⁰ From the 2016 Scottish IO table of total household spending in Scotland, around 20% on imports from UK and 10% from rest of the world,

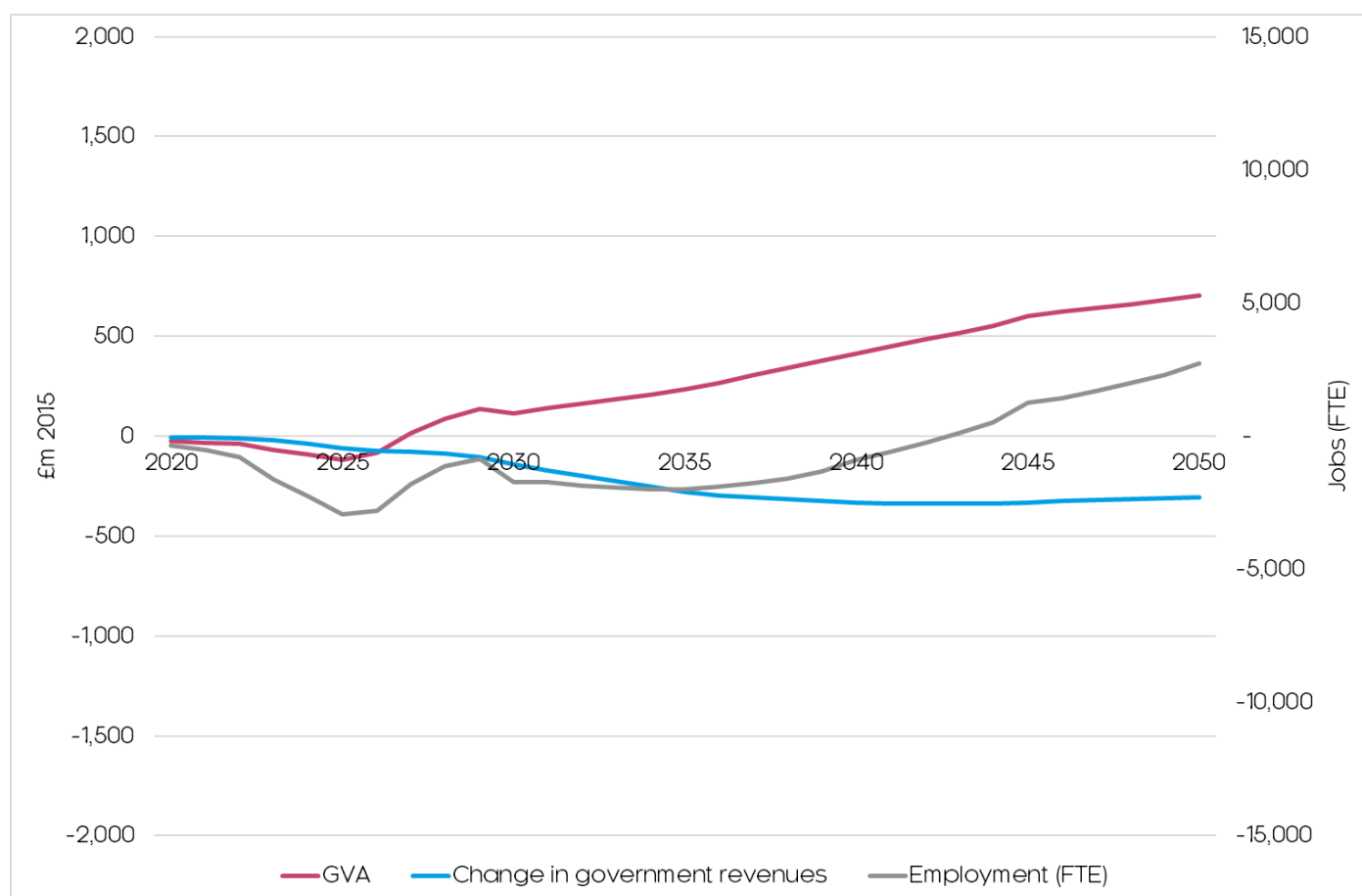


Figure 2: Economic impacts of the transition to ULEVs

However, employment is lower for much longer. Initially, this is because the more expensive vehicles displace spending on other goods and services, and the jobs in vehicle/component manufacturing have higher productivity than the activity they are replacing (and therefore fewer jobs are created than are lost from the shift in sectoral activity). In addition, the transition to ULEVs leads to a reduction in jobs in vehicle repair and maintenance and in refuelling infrastructure, which for ICEs are both relatively labour intensive compared to the ULEV equivalents. For example, ULEV powertrains have fewer moving parts requiring maintenance while EV charging moves away from centralised refuelling stations to a substantial proportion of home charging.

Analysis of the impacts highlights that a significant transition takes place over the period, with clear winners and losers. Many of the job losses are due to the fall in ICE sales and resultant falls in motor vehicle manufacturing (-1,700 jobs), fuel supply and distribution (-5,900 jobs) and repair and maintenance (-10,600 jobs). In most cases, this is partially offset by jobs created in the ULEV equivalent activity (+15,200 jobs), but jobs are also created because savings from the lower cost of road transport are spent elsewhere in the Scottish economy.

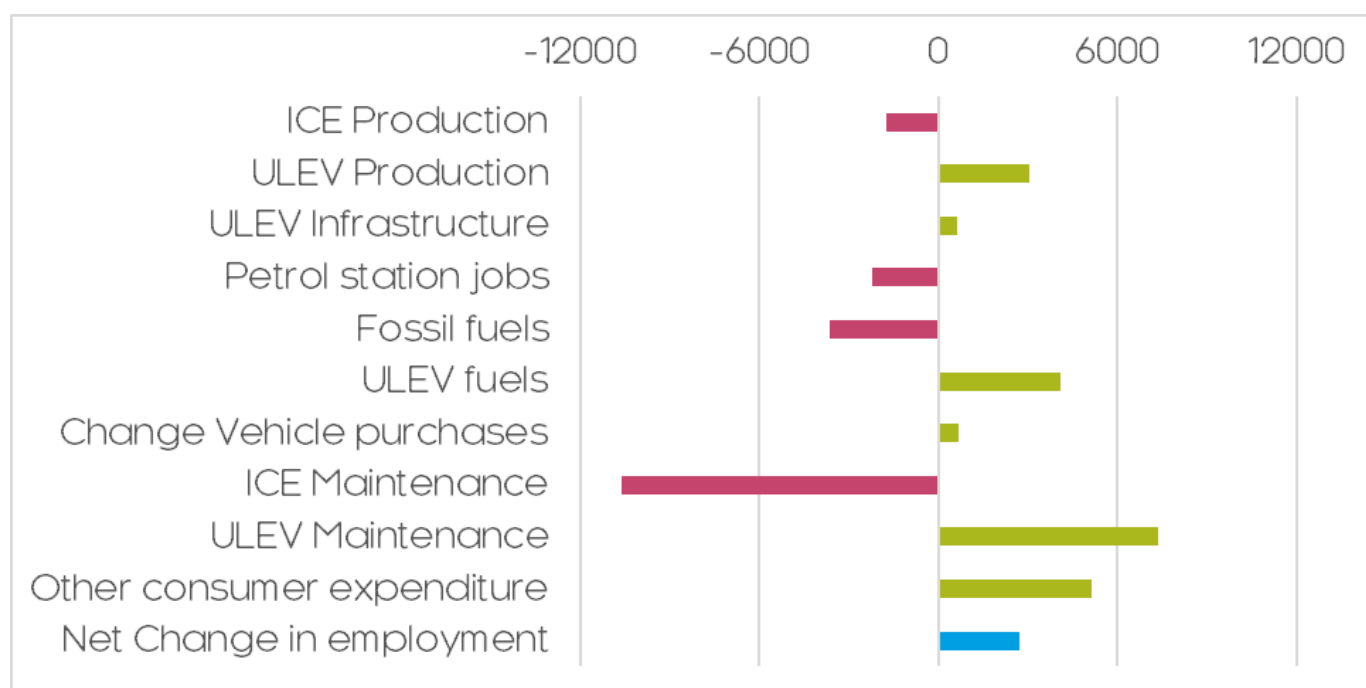


Figure 3: Change in employment in Scenario 3 in 2050 by component

There is a small reduction in net tax take in Scotland of around -£300m by 2050. In this scenario, we assume the fall in fuel duty is compensated for by an equivalent taxation on road users to prevent a rebound in travel demand (this is an input assumption to the framework, based on Element Energy's previous work). VAT is slightly lower overall (-£360m), as the foregone VAT from fossil fuels (including fuel duty) is more than the additional VAT raised from electricity (which is subject to only 5% VAT, compared to 20% on fossil fuels). Corporation tax is slightly higher (+£60m) as a result of the increased activity in the economy as a whole. In addition, we do not capture changes in income tax, which would be expected to produce greater revenues in the long term due to higher employment in the Scottish economy.

4.2.2 Environmental results

The environmental impacts are positive and substantial. Reductions in NO_x and PM2.5s are measured, and monetised based upon health damage coefficients from DEFRA, while CO₂ emissions are quantified and monetised based upon the Social Price of Carbon recommended by HM Treasury for use in assessing CO₂ emissions in non-traded sectors (i.e. those outside of the scope of the EU ETS). Monetising the emissions reductions in this way shows a total net benefit of £1.08bn (not discounted) in 2050.

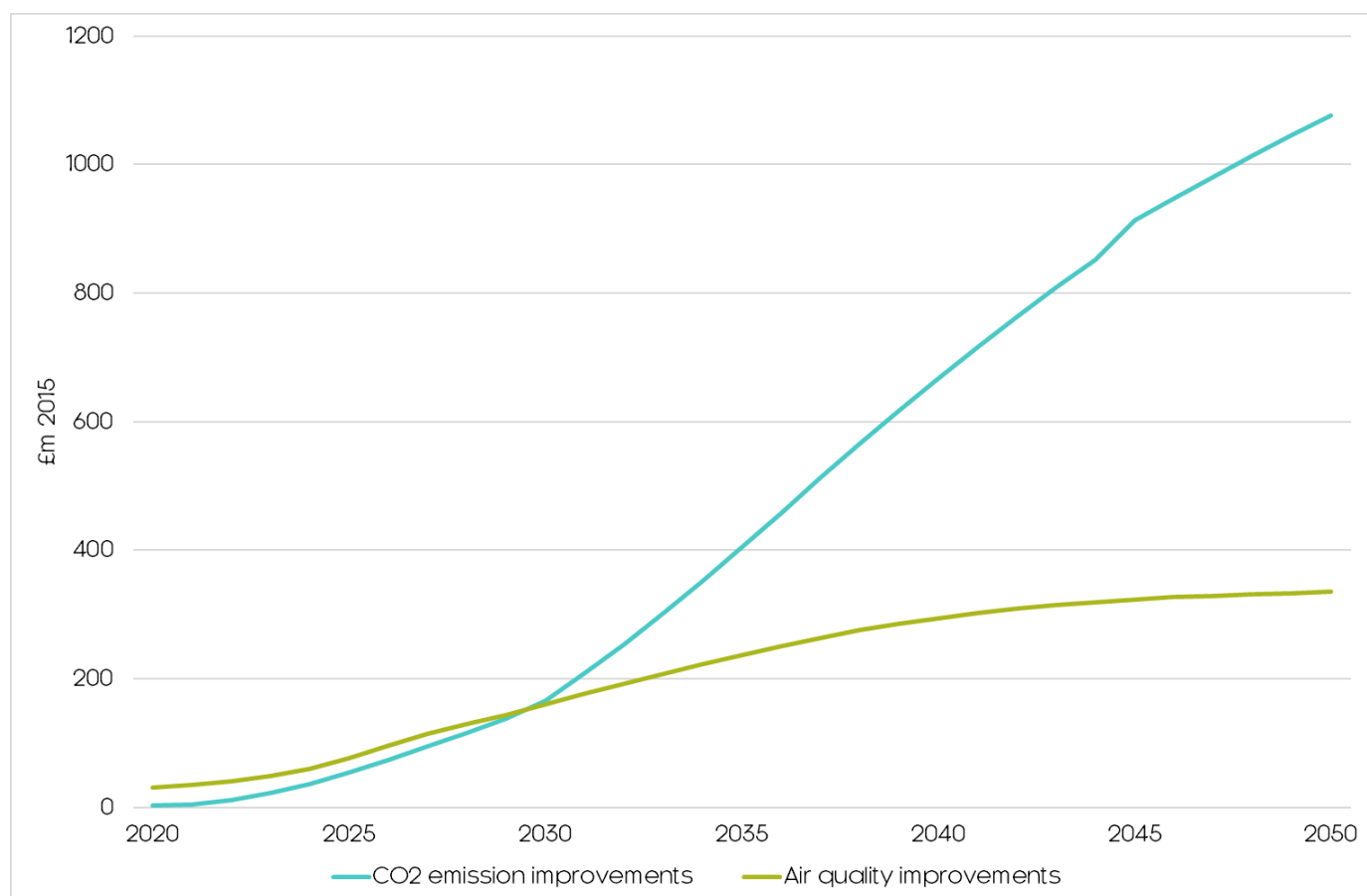


Figure 4: Environmental impacts of the transition to ULEVs

4.3 Scenario comparison

As a sensitivity, we explored the difference in the economic impact of ULEVs between Scenario 2 and Scenario 3 to show the difference in the impact of deployment under different levels of transport demand.

In the short term, the higher costs of deploying ULEV vehicles is amplified in Scenario 2 relative to Scenario 3 so more money is spent in the less labour intensive ULEV production than in the wider Scottish economy.

Over the longer term (post 2033), the economic impacts are relatively similar both in terms of GVA and jobs. Scenario 2 show slightly larger impacts reflecting the larger Scottish vehicle fleet in this scenario and so a proportionally larger benefit from switching that fleet from ICEs to ULEVs.

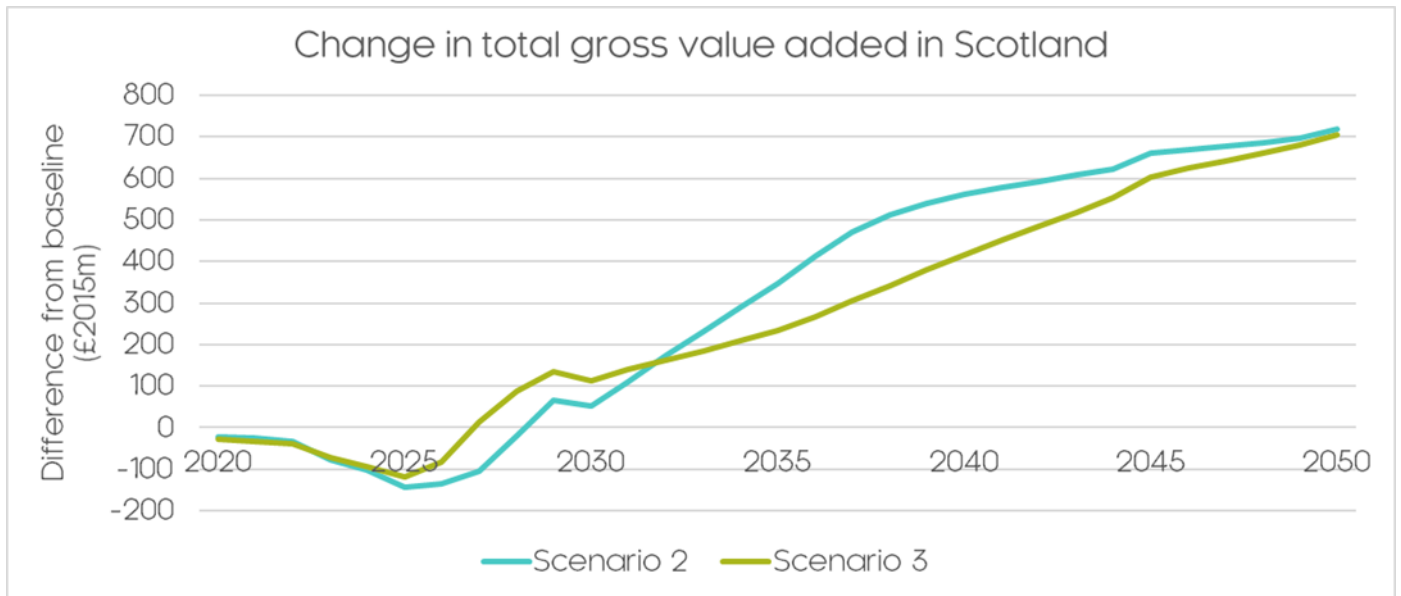


Figure 5 : Gross Value Added (in 2015m) impact of the transition to ULEVs for scenarios 2 and 3 relative to the baseline scenario

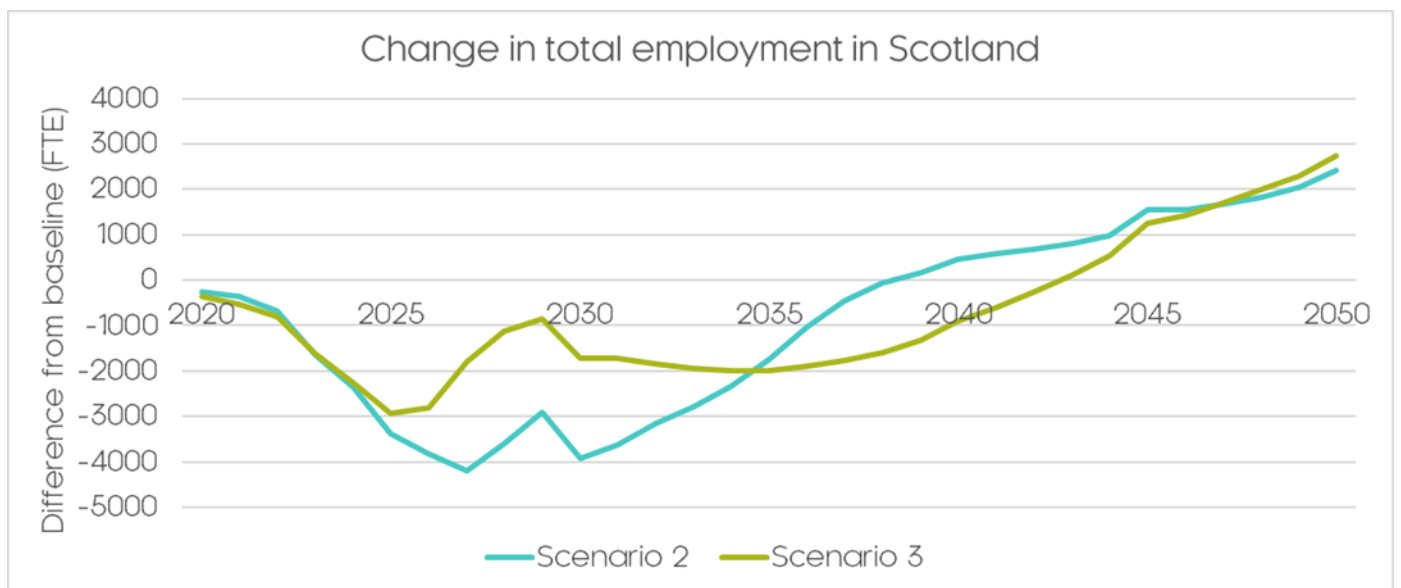


Figure 6 : Employment impact of the transition to ULEVs for scenarios 2 and 3 relative to the baseline scenario

5 Policy Implications

The impacts set out in the previous chapter highlight the role for the Scottish Government in helping to manage the transition and its socioeconomic effects. Below we set out policy recommendations which address some of the key impacts highlighted in the analysis.

5.1 Overarching Policies

This analysis assumes that fiscal measures are introduced to avoid the shift from ICEs to ULEVs reducing the cost of transportation which could lead to an increase in demand for transportation. A positive side effect of this is that it reduces substantially the impact of lost fuel duty on government revenues, a key negative outcome of the transition. Electric vehicles can be charged from a range of sources, including users' homes, making it hard to differentiate the electricity used for transport from that used for other purposes (and therefore making it difficult to introduce an equivalent tax on electricity used in vehicles).

In the absence of a fuel duty for electricity used in transport, the lower running cost per kilometre of pure electric vehicles would lead to a rebound in demand for transport (i.e. demand increasing as a result of a lower price). Extra journeys are undesirable in the context of Scotland's net-zero ambition: they add to the burden of maintaining and managing Scotland's highways and, since some electricity used in Scotland is still generated from fossil fuels, additional electric-powered journeys would produce more emissions (at least for as long as this electricity generation mix persists).

For hydrogen, the expense of the production, distribution and refuelling infrastructure required is likely to result in a more expensive option than incumbent fuels. As there are few ULEV alternatives to hydrogen in certain vehicle segments such as trucks, keeping the fuel price as low as possible will be necessary to encourage uptake, leaving little room for additional fuel duties. As hydrogen is sold in a similar way to petrol and diesel, a fuel duty could be introduced for hydrogen once the fuel is established, but this is unlikely to be possible until at least 2030.

The analysis in this report assumes that a policy such as a 'road tax' is introduced to align transport costs. A road tax could be a highly flexible policy, based on number plate recognition technology, to differentially charge drivers for their use of Scotland's roads. This would allow certain categories of user, such as those with ULEVs or on low incomes, to be exempted, while increasing the cost of operating the most polluting vehicles. Such a scheme could charge different rates at different times of day to tackle congestion (and other outcomes such as human health impacts) as well as emissions.

5.2 Sector Specific Policies

5.2.1 Vehicle production

Around 4,000 people are employed directly in automotive manufacturing in Scotland¹¹, in addition to 4,000-5,000 in the wider supply chain¹². Those directly employed are predominantly at Alexander Dennis, a major bus manufacturer, which employs 2,500 people mostly at its Falkirk site. Our analysis suggests that c.1,700 of these jobs could be lost due to the transition to ULEVs, as certain roles and skills will no longer be required.

¹¹ Rhodes, C. (2019). The motor industry: statistics and policy. House of Commons Library. Retrieved from <https://researchbriefings.files.parliament.uk/documents/SN00611/SN00611.pdf>

¹² UK Government. (2017). Automotive Sector Report. Retrieved from <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Sectoral%20Analyses/4-Sectoral-Analyses-Automotive-Report.pdf>

As automotive manufacturing shifts to ULEV technologies, many current workers will continue with the same employer but require re-training to develop the skills specific to these new technologies. There is also potential for the creation of around 3,000 new jobs in producing ULEV vehicles, based on existing activity in electrical equipment manufacture. Scotland has extensive expertise in electrical engineering, and a pool of electrical engineers that could be attracted to work in the automotive sector if new opportunities were created - Scotland currently has very little vehicle production capacity.

Cities have significant control over the procurement of buses and are increasingly coming under pressure to shift to zero-emission fleets – London has the most ambitious UK plans, with aims to have a fully zero-emission bus fleet by 2037. Leeds, Birmingham and Bath will have 'Clean Air Zones' in 2020 that charge non-compliant vehicles a daily fee for driving in certain areas of the cities. In Scotland, the government has mandated Glasgow, Edinburgh, Dundee and Aberdeen to create 'Low-Emission Zones' which will ban the most polluting vehicles entirely from certain areas. In Glasgow, the roll-out of these zero-emission buses has already started; they are provided by Alexander Dennis, and constructed in Falkirk, highlighting the potential for Scottish manufacturing in the segment.

Over the next five years these measures will force heavy-duty vehicle (HDV) (trucks, coaches, buses) operators to start transitioning their fleets to zero-emission vehicles. However, it is clear from established vehicle original equipment manufacturers (OEMs) that their plans for zero-emission vehicle production are much lower than expected demand. This presents an opportunity for Scottish manufacturers. While it would be challenging for Scotland to compete with the large production volumes of established global manufacturers of ULEVs in the car and van segments, it could have an advantage in the HDV segment. Little progress has been made globally in the shift to heavy-duty ULEVs which involves smaller volumes and greater specialisations; Scotland has the potential to increase its manufacturing capacity to meet this gap.

Policies

- **Grant funding for Scottish companies developing or retrofitting ULEVs.** Government support for existing vehicle producers in this area, such as Alexander Dennis, could help them capture a larger share of this growing market. It is also expected that the number of companies producing retrofit electric trucks will increase: the retrofit process, especially on rigid trucks, is relatively straightforward. Grant funding for small start-ups in this area will help Scotland capture some of the value of this new area and help to meet its own climate targets.
- **Existing jobs should be protected through retraining.** Employees at Scottish companies currently manufacturing ICE vehicles or components have many transferrable skills that could be applied to ULEV technologies. Companies will require support to provide the necessary re-training for their workforce; the government can ensure relevant training schemes are established, and that funding is made available to companies that retrain their staff.

5.2.2 Petrol stations

As ULEVs are adopted and replace petrol and diesel vehicles in the fleet, associated jobs at refuelling sites will be lost - our analysis suggests this could be as many as 2,500 jobs across Scotland by 2050. Most jobs at petrol stations are essentially in retail rather than directly linked to the sale of fossil fuels, but it is expected that the reduced demand for refuelling from such specialist sites (as ULEV charging needs are partially met through home charging) will lead to a decrease in the number of refuelling stations that can be economically supported by the fleet, leading to a loss of jobs.

This transition will be particularly challenging as sites may need to maintain a range of new refuelling options (e.g. rapid chargers or hydrogen dispensers) alongside continued provision of petrol and diesel to attract sufficient customers. The longer periods of time that customers are

likely to spend at sites while their electric vehicles charge adds complexity; there is an opportunity to provide additional services, but sites that fail to provide these effectively will lose out to more attractive ones.

This presents a particular challenge in Scotland's many rural areas where the closure of petrol stations would have a detrimental impact on quality of life if residents are forced to travel significantly further to refuel. Rural petrol stations also often serve as community hubs, providing a range of services such as post offices and convenience stores. In addition to the local communities they serve, many rural areas are dependent on tourism; there will need to be sufficient refuelling and recharging infrastructure as the volume of ULEVs amongst tourist vehicles increases.

Some petrol stations may require support to transition their businesses away from dependence on providing fossil fuels through diversifying their services. Others will need support to manage the shift to supplying different fuels. The Rural Petrol Stations Grant (RPSG) Scheme, which provided a 50% grant towards essential investment on refuelling infrastructure at petrol stations, proved successful in stimulating deployment of Liquid Petroleum Gas (LPG) at rural petrol stations¹³. A similar scheme should be used to support deployment of ULEV infrastructure.

Policies

- **Rural petrol station grants / rural essential facilities grant.** Rural petrol stations often already operate on small margins and will require government support to continue to provide low-volume refuelling for remote communities. This could build on the success that the previous RPSG had in stimulating investment in LPG infrastructure.
- **Zero-interest loans to help all independent petrol stations install new facilities on site.** As fuel sales fall, petrol stations can remain profitable by expanding the services they offer, such as charge points or retail. Taking advantage of these opportunities will require investment and the government can encourage this by offering zero-interest loans for improving facilities.

5.2.3 EV charging infrastructure

Infrastructure for ULEVs, such as charge points for EVs and hydrogen dispensers for fuel cell electric vehicles (FCEVs), are produced by large multinational manufacturers such as ABB, Siemens and BOC/Linde, with limited opportunities for new Scottish entrants. There are, however, significant opportunities for Scottish companies to install and operate ULEV infrastructure – representing about 500 potential new jobs according to our analysis. Ensuring this new infrastructure is deployed to a high standard will unlock the greatest benefits to the wider economy.

The deployment of charging infrastructure in the UK to date has highlighted challenges that will need to be overcome in Scotland. EV charging is a different proposition to traditional refuelling (and to hydrogen refuelling which is comparable to the current experience) as customers need to park up for a prolonged period while their batteries charge. This provides an opportunity to provide additional services at EV charging locations, but facilities need to be carefully thought through to ensure wider economic benefits are realised. Well-designed charging sites are needed that consider the following:

- **Rapid charging:** charge points should be sufficiently powerful to ensure customers can charge quickly enough so that public charging does not become an inconvenience.

¹³ Gleave, S. D. (2004). Review of the Rural Petrol Stations Grant Scheme. Retrieved from <https://www2.gov.scot/resource/doc/17002/0029572.pdf>

- **Compatibility:** charge points should be compatible across all vehicles and charging standards to ensure EVs can recharge at any location.
- **Payment interoperability:** deployment of charging infrastructure to date has led to a range of different providers with different payment systems, meaning that some users are excluded from using certain chargers. Ensuring payments work across all providers is essential to widespread adoption of EVs in Scotland. The requirement to accept pay-as-you-go payments is an approach often taken to ensure access to all.
- **Co-location with other services:** rapid charging sites should be near destinations that people want and need to visit. Motorway services are a clear example, but to ensure the shorter range of EVs compared to ICEs does not become a barrier to adoption, public charge points should be deployed strategically, and in sufficient numbers, to avert 'range anxiety'.
- **On-street charging near homes:** about 75% of charging currently takes place at home¹⁴, but this is not possible for the 34% of cars and 28% of vans in Scotland that use on-street parking¹⁵. If EVs are to make up the 94% share of private cars in 2050 projected in this scenario, some on-street charging in residential neighbourhoods is likely to be needed.
- **Interaction with the energy system:** the projected uptake of EVs could have a major impact on the wider electricity system if the corresponding power demand is inflexible. This would generate additional costs associated with strengthening grid infrastructure. There are, however, opportunities for 'smart charging' to mitigate these impacts and add value by helping to balance increased supply of electricity from intermittent renewable resources in Scotland.

5.2.4 FCEV refuelling infrastructure

The hydrogen refuelling infrastructure implied by the FCEV uptake projected in this study suggests that a significant share of the ULEV infrastructure jobs will be in this segment. Hydrogen refuelling requires substantially different infrastructure to EV charging which is able to use the existing electrical grid. HRSs require a supply of hydrogen which can either be trucked to the site or produced in-situ with an on-site electrolyser. Beyond this, there is a need for high pressure storage, compression and dispensing infrastructure, all of which requires a skilled workforce to install and maintain.

In the scenario we analysed, FCEVs dominate the ULEV truck segment; these vehicles will require the bulk of the hydrogen supplied for transport in Scotland. Trucks generally require separate refuelling facilities from the public sites that are suitable for EVs. The business case for companies interested in building and operating this infrastructure is likely to be dependent on support from the government early on to mitigate the dual risks of i) lower than expected volumes of FCEVs, and ii) constraints in supplies of hydrogen in Scotland.

Hydrogen vehicles are currently at a much lower level of development than other ULEVs but evidence from early deployment projects suggests that several aspects should be considered as the infrastructure is rolled-out:

- **Scale:** deploying hydrogen as a transport fuel is expensive at a small scale, creating challenges during the early stages of development. While production facilities lack

¹⁴ Element Energy. (2019). Electric Vehicle Charging Behaviour Study. Retrieved from <http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/04/20190329-NG-EV-CHARGING-BEHAVIOUR-STUDY-FINAL-REPORT-V1-EXTERNAL.pdf>

¹⁵ climateXchange. (2019). ULEV Market Segmentation in Scotland. Retrieved from <https://www.climateexchange.org.uk/media/4005/cxc-ulev-market-segmentation-in-scotland.pdf>

economies of scale, refuelling infrastructure is underutilised and the timelines for large scale deployment of vehicles are uncertain. Government support will, therefore, be required to encourage early investment. At scale, hydrogen offers an effective decarbonisation option for heavier-duty vehicles that lack alternatives.

- **Emissions:** hydrogen can be produced from a range of sources, with varying costs and resulting emissions. Reformation of natural gas to produce hydrogen is an established technology but requires deployment of CCUS technology to become a 'low carbon' option. 'Zero-carbon' electrolytic hydrogen can be produced by using renewable electricity and can provide additional services to the grid by absorbing excess electricity production. These technologies are at an earlier stage of development while electrolytic hydrogen is typically more expensive than hydrogen from reformation.
- **Clusters:** deploying hydrogen infrastructure in 'clusters' helps to reduce costs and increase reliability when early adopters of FCEVs have limited opportunities to refuel their vehicles. An example is the cluster being developed in Aberdeen which is focused around a refuelling station supporting a fleet of 10 hydrogen buses and a range of other hydrogen vehicles.

The rollout of ULEV refuelling infrastructure in Scotland provides an opportunity to increase the revenue generated in the sector by creating high-quality refuelling options for vehicles that provide international transport. Many journeys made in Scotland by trucks, trains and ships start or end in the rest of the UK or in other countries. By offering the best refuelling options for these vehicles along their routes and supplying certified green fuels, ULEV refuelling sites could capture significant value that is currently generated elsewhere.

Policies

- **Charging and hydrogen refuelling station standards to ensure highly functional infrastructure is installed.** To maximise the benefits from new refuelling options, the stations must be high quality and ensure a quick and easy experience for users, similar to that currently experienced using conventional refuelling. This means ensuring all charging points are accessible to all users, that they are sufficiently powerful and are effectively maintained to avoid downtime.
- **Development of an infrastructure plan to help ensure the rollout of infrastructure meets needs of users and suppliers.** This includes ensuring that infrastructure is ready ahead of demand so that a lack of refuelling options does not become a limiting factor for uptake of ULEVs. An effective rollout strategy is particularly important for hydrogen infrastructure which requires a more complicated supply chain and which should focus on deploying clusters such as in Aberdeen.
- **Ensure planning does not prevent the best siting and quick rollout of infrastructure.** Planning procedures have often added significantly to the timeline for deployment of hydrogen refuelling infrastructure. The same can also be true for EV charging infrastructure which requires significant grid connections. We recommend reviewing planning procedures so that they do not unduly inhibit deployment of these facilities.
- **Ensure good infrastructure at key points** (train stations, ports, the border etc.) to try and capture fuel use of international vehicles: foreign vehicles passing through Scotland offer an opportunity to attract additional revenue for ULEV infrastructure. Often vehicles such as trucks will have significant flexibility as to where to refuel and, by providing superior facilities to those found elsewhere, Scotland can sell greater volumes of domestically-produced renewable transport fuel to foreign companies.

5.2.5 Fuel production

Scotland is currently a major beneficiary of the economic activity created by the offshore oil and gas industry in the waters around the UK. Just under 30,000 Scottish jobs are directly attributed

to the sector, while 110,000 jobs across Scotland in total are linked to the industry through supply chains¹⁶. Around 4,000 of these direct jobs are expected to disappear by 2050 as a result of the transition to ULEVs in Scotland, according to our analysis.

Despite this, many of the existing skills and much of the infrastructure already in place for servicing the offshore industry can be repurposed to support the transition. One example is the opportunity, recognised in the UK Government's Clean Growth Strategy, for the development of a CCUS industry in the UK. Amongst other benefits, CCUS can help to decarbonise the process of reforming natural gas to make hydrogen which could be used as a 'low-carbon' fuel for FCEVs while technologies mature to produce fully renewable 'zero-carbon' hydrogen through electrolysis.

The UK has some of the largest carbon storage potential in Europe, with a theoretical capacity to store 78 Gigatons (Gt) of carbon¹⁷ – in 2017 the EU's total carbon equivalent emissions were 4.5Gt¹⁸. Much of the UK's storage potential is in the North Sea, off the east coast of Scotland. Existing infrastructure that delivers oil and gas from offshore platforms could be repurposed to provide CO₂ transport to depleted wells and other geological opportunities for CO₂ storage. The scale of the storage potential is well beyond the carbon emissions of Scotland or the UK, suggesting this could be a major opportunity for Scotland to generate income from providing carbon storage for other countries across Europe.

In addition to the opportunities in CCUS, the transition to ULEVs implies a significant increase in demand for electricity, and the development of a new industry to produce and distribute hydrogen. Despite large quantities of crude oil being produced in Scotland, only about three quarters of the annual demand for petrol and diesel used in Scottish road transport is refined in the country, with the rest imported from elsewhere. Scotland's abundant renewable resources for generating electricity from wind, wave and tidal energy offer an opportunity for the country to produce all its transport fuels domestically. The existing skills and infrastructure for producing fossil fuels and chemicals could be leveraged to produce low- and zero-carbon fuels for the ULEV fleet and continue to earn additional revenue by exporting excess production.

Policies

- **Support CCUS deployment projects.** Existing infrastructure and skills in Scotland associated with the oil and gas industry make Scotland an ideal location for the development of CCUS technologies. Ensuring that this technology is ready for large-scale deployment will both aid the domestic production of ULEV fuels and create new employment opportunities as jobs are lost in supplying fossil fuels.
- **Fund appraisal of CCS storage sites.** Government funding is required for further appraisal of storage units to prove Scottish CO₂ storage capacity and aid the development of CCUS projects.
- **Grants/zero-interest loans for rural communities to develop renewable generation paired with new refuelling sites.** There is an opportunity for Scotland's more isolated communities to produce their own transport fuels for ULEVs. With decentralised

¹⁶ Oil & Gas UK. (2018). Workforce Report 2018. Retrieved from <https://oilandgasuk.co.uk/wp-content/uploads/2019/03/OGUK-Workforce-Report-2018.pdf>

¹⁷ ETI. (2016). Progressing Development of the UK's strategic carbon dioxide storage resource. Retrieved from <https://s3-eu-west-1.amazonaws.com/assets.eti.co.uk/legacyUploads/2016/04/D16-10113ETIS-WP6-Report-Publishable-Summary.pdf>

¹⁸ European Environment Agency. (2019). Total greenhouse gas emission trends and projections in Europe. Retrieved from <https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-3>

electricity generation from wind, wave and solar, both electricity for electric vehicles and hydrogen for FCEVs can be created at or near refuelling sites. An example is the ReFLEX project in the Orkney Islands which aims to make the islands self-sufficient in zero-carbon energy including hydrogen production for ULEVs.

5.2.6 Vehicle maintenance

The main source of job losses in Scotland from the transition to ULEVs is likely to be in companies providing repair and maintenance services for ICE vehicles. This is due to the substantially different skills required to work on conventional and ULEV vehicles, as well as the generally lower maintenance costs associated with ULEVs due to their fewer moving parts. The current lack of relevant skills to work on these vehicles has been highlighted by BEIS, which notes there are just 1,600 technicians qualified to work in this segment in the UK¹⁹.

Owners of ICE vehicles tend to use small local garages for maintenance services; in Scotland there are over 1,300 of these companies registered with the Scottish Motor Trade Association. The different skills and tooling required for maintaining EVs has so far meant that this work is overwhelmingly carried out by the dealerships that sell the vehicles, rather than by local garages; servicing ULEVs is becoming a key part of the business model of dealerships. As the number of ULEVs on the road increases, the proportion of the fleet that conventional garages can work on is expected to fall, leading to closures and job losses.

To some extent these job losses will be offset by the creation of jobs at ULEV dealerships providing in-house maintenance services. However, due to the extensive retraining required to work on high-voltage ULEV systems, these are likely to be a different set of workers to those currently employed at ICE vehicle garages. There are a number of ways to mitigate the risk of these job losses, including by ensuring that training programmes begin to focus on EV rather than traditional technologies. As the fleet transitions over the next 20 years, there is enough time for many of today's ICE mechanics to retire before demand for their skills disappears, but this is not true for those that begin their careers in the next few years.

There is also an opportunity for local Scottish garages to refocus their businesses to provide services that are relevant to ULEVs. The bulk of the work carried out on conventional vehicles is in replacing parts that wear out such as tyres, brake pads and air filters rather than in servicing the engine and power transmission systems. While local mechanics are unlikely to be able to work on ULEV power systems, there will be opportunities for specialising in these ancillary components. This will not be an easy transition for independent businesses and they will require support from the government to make this shift.

Policies

- **Expand existing training programmes for ULEV technologies.** Many existing workers maintaining ICE vehicles will still be required during the transition to ULEVs, but will need additional training to carry out ULEV-specific tasks, as these vehicles become a more prominent part of the fleet. Funding for ULEV-specific training is already in place in Scotland, but these programmes should be expanded given the significant changes in job requirements in vehicle maintenance, and their importance to the overall economic impact of the ULEV transition. These programmes should ensure new entrants to this sector are trained in the new technologies to prevent them embarking on careers focused on ICEs which will not provide long-term employment opportunities.
- **Provide support for garages to make the shift to servicing ULEVs.** There will be opportunities for local garages to provide maintenance for ULEVs, but this will require staff retraining and a restructuring of their businesses towards these new technologies.

¹⁹ BEIS. (2018). Electric vehicles: driving the transition. House of Commons. Retrieved from <https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/383/383.pdf>

Government loans or grants could help cover these small businesses' associated costs and position them to benefit from the transition.

- **Ensure there are wider training opportunities to take advantage of the net increase in jobs across the economy.** The reduced maintenance requirements of ULEVs means that there will be fewer employment opportunities in the vehicle maintenance sector. However, the net economic benefit to the economy from the shift to ULEVs means that there will be additional opportunities elsewhere in the economy. Training schemes will be needed to make sure workers are able to take advantage of these opportunities.

6 Conclusions

In this study, we developed a quantitative framework to assess the socioeconomic impacts of the deployment of ULEV vehicles in Scotland. This framework was applied to two scenarios for future ULEV deployment, most notably, “Scenario 3”, a scenario developed by Element Energy for Transport Scotland which specifically meets the Scottish Government’s stated policy to remove the need for new combustion engine vehicles by 2032.

The quantitative assessment of this scenario finds that the economic impacts are positive over the long term. GVA is higher in the scenario than in the baseline (in which ULEV deployment remains in proportion with that which occurred in 2018 in Scotland) across all years from 2027 to 2050. In the short term, GVA is lower, as a result of the higher investment costs and the high price of ULEVs (relative to ICEs), which reduces the disposable income of consumers. Employment (on an FTE basis) remains below baseline for most of the period, although by 2043 total economy-wide employment is higher, as a result of shifts in economic activity.

At the same time, there are substantial environmental benefits. CO₂ emissions are reduced by 113m tonnes or 49% cumulatively over 2020-2050, and the improvements to air quality from the annual reduction in tailpipe emissions of NO_x and PM_{2.5}s are estimated to reduce damage to human health by the equivalent of £335m in 2050 alone.

Based upon these findings, we have identified a number of policy areas for the Scottish Government to consider to exploit the benefits of the transition, and to address some of the challenges.

We suggest two areas require the most urgent action, based on the scale of economic activity which is likely to be displaced in the transition.

First, we highlight ICE maintenance jobs as being most at risk from the transition to ULEVs: the framework shows that more than 10,000 vehicle maintenance jobs could be lost in Scotland. This is because ULEVs require less maintenance due to fewer moving parts, and because their high-voltage drivetrains require specific skills (and therefore training) before they can be maintained. While ICE vehicles are generally maintained at local garages, dealerships are often the only place where maintenance can be done on ULEVs. The jobs at risk are likely to be distributed widely across Scotland, reflecting the geographic distribution of maintenance garages.

The transition to ULEVs can represent an opportunity for these businesses, but they will require support to retrain their employees and refocus their businesses towards the services and parts required by ULEVs. While some job losses in this sector are probably unavoidable, overall the transition is expected to provide a net addition of jobs to the economy. As such, support should be given to those that lose their jobs to find employment elsewhere in the economy. In addition, action should be taken now to ensure new entrants to the sector receive training that will be relevant to the ULEVs expected to be on the roads in future.

The second area of policy focus relates to Aberdeenshire’s strong dependence on the oil and gas industry. Some 30,000 people are directly employed in the oil and gas sector in Scotland²⁰, and we have estimated that around 4,000 of these are at risk from the transition to ULEVs as demand for oil within Scotland falls.

However, the transition to ULEVs also offers opportunities in adjacent industries, if the government provides the necessary support to develop a zero-carbon fuels industry. The extensive infrastructure and skills already in place in Scotland for servicing the offshore oil and gas industry provide a strong foundation for Scotland to further exploit its renewable offshore

²⁰ Oil & Gas UK. (2018). Workforce Report 2018. Retrieved from <https://oilandgasuk.co.uk/wp-content/uploads/2019/03/OGUK-Workforce-Report-2018.pdf>

resources. This includes using renewable electricity to produce zero-carbon hydrogen for use in vehicles (and in the electricity generation and other final use sectors), as well as opportunities to reduce emissions across the economy by putting carbon capture, utilisation and storage (CCUS) infrastructure in place.

Appendix A

User guide

In this Appendix we explain how to use the framework tool. There are three key parts to the user interface:

- inputs: selection of different scenarios;
- sensitivities: selection of available sensitivities; and
- results: viewing the results.

Scenario Inputs

The main inputs for the analysis are the shares of sales by powertrain and whether the stock is defined or not; these can be found in the 'Scenario Inputs' tab. There are two tables, one for each scenario. The first (share of sales) is located at cell B14 (as seen in Figure 7 below). It is important that the user ensures the shares total 100% for each vehicle segment.

Sales and stock inputs

Sales by Powertrain input assumptions							
Scenario 1		2020	2021	2022	2023	2024	2025
ICE	Passenger	86%	78%	70%	62%	53%	41%
HEV	Passenger	2%	2%	2%	2%	1%	1%
PHEV	Passenger	4%	6%	9%	11%	13%	18%
BEV	Passenger	7%	12%	18%	23%	29%	36%
FCEV	Passenger	1%	1%	2%	3%	3%	4%
ICE	Vans	86%	78%	70%	62%	53%	41%
HEV	Vans	0%	0%	0%	0%	0%	0%
PHEV	Vans	6%	8%	10%	12%	15%	19%
BEV	Vans	7%	12%	18%	23%	29%	36%
FCEV	Vans	1%	1%	2%	3%	3%	4%
ICE	HDV	86%	78%	70%	62%	53%	41%
HEV	HDV	0%	0%	0%	0%	0%	0%
PHEV	HDV	6%	8%	10%	12%	15%	19%
BEV	HDV	7%	12%	18%	23%	29%	36%
FCEV	HDV	1%	1%	2%	3%	3%	4%

Figure 7: Sale shares by powertrain

Each scenario has the option to input absolute sales for each vehicle segment. The first table can be found at C7 in the 'Scenario Inputs' tab - see below.

Scenario 1			
Sales projection	2020	2021	2022
Passenger Car	211,479	211,101	211,084
Vans	29,044	28,370	27,841
HDV	2,992	3,000	3,005
Bus	966	945	914
Car sharing of s	0%	0%	0%

Figure 8: Input for absolute sales by vehicle segment

Each subsequent table is found below the scenario heading: "Scenario 2" and "Scenario 3".

The user also has the option to set the percentage of car sharing in the stock. The car sharing assumption adjusts the average vehicle mileage of the stock to reflect that vehicles used for car sharing travel significantly further as they are used more. The adjustment to average mileage can be found in the 'Vehicle mileage' sheet of the framework.

The other table is located at cell B38. This table includes the size of the stock by powertrain. The user has the option to define the stock here if they wish to use their own stock projections; these will override the vehicle stock calculation in the framework.

To use the user-defined stock for a scenario, the user must set stock definition to True, via the dropdown tab on the Results summary page at cell C5 (Figure 9).



Figure 9: Define stock calculation

Scenario selection

The ULEV framework can only calculate results for one scenario at a time, i.e. either Scenario 2 or Scenario 3. The user can toggle between the two using the dropdown located in the 'Results summary' tab at cell C4.



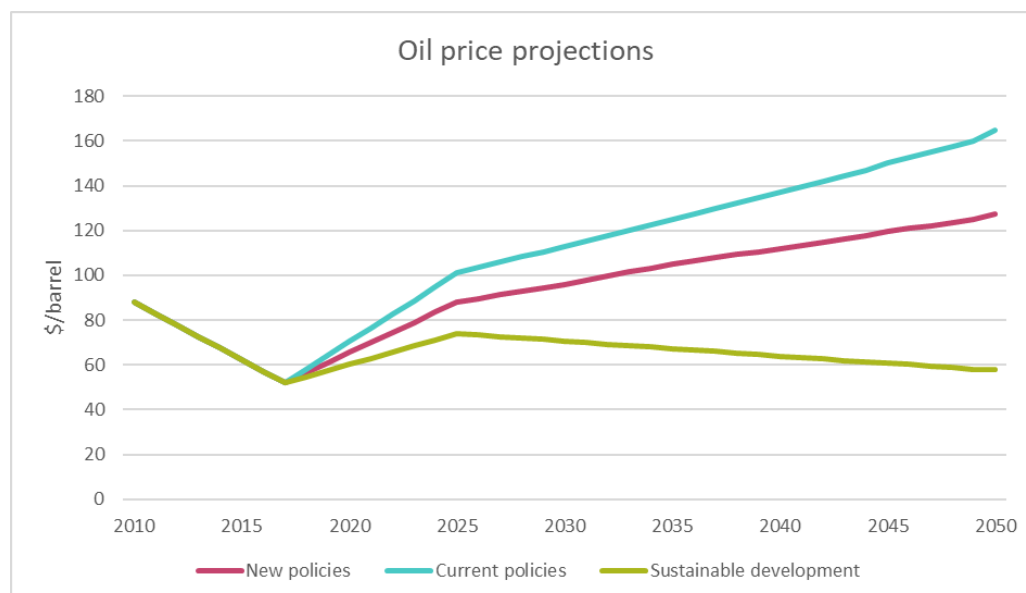
Figure 10: Scenario selection

Sensitivities

Due to uncertainty over future oil prices and complexity in estimating the damage coefficients of emissions, sensitivities, from the respective original source, can be tested in the framework.

Oil price sensitivity

The oil price used to project the fuel price of middle distillates for ICEs is from the International Energy Agency World Energy Outlook (2018). In this report, three scenarios are modelled which give three different oil price projections: New policies, Current policies and Sustainable



development.

Figure 11: Oil price sensitivities

All three scenarios are included in the report as sensitivities for the analysis based on the fuel price. The user can select which oil price projection in 'Results summary' tab in cell D81.

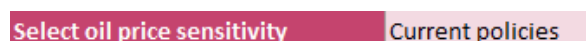


Figure 12: Oil price selection

Damage coefficient sensitivity

The damage coefficients (Defra, 2019) include a low, central and high estimate of the potential damage from NO_x and PM2.5. The user can toggle between these sensitivities in the 'Results summary' tab in cell D175.


 A screenshot of a dropdown menu. The text 'Select damage coefficient sensitivity' is in a pink box, and 'Low' is selected and highlighted in a lighter pink box.

Figure 13: Emission factor selection

Type I and Type II multipliers

Supply chain effects in the framework can be calculated based on either:

- Type I multipliers (direct and indirect effects) or
- Type II multipliers (direct, indirect and induced effects).

The user can choose which one in the 'Results summary' tab at cell C6.


 A screenshot of a dropdown menu. The text 'Multiplier:' is in a teal box, and 'Type II' is selected and highlighted in a light blue box.

Figure 14: Multiplier selection

Results Summary

The summary of all results in the different impact areas can be found in the 'Results summary' tab. It includes the tables summarising the main results, supply chain impact for the first two impact areas and the relevant final results of the other impact areas (e.g. damage costs), and charts. All results are split by the different vehicle segments: Passenger Car, Vans, HDV and Buses. For more detail on the individual components that are part of the calculation of results (by powertrain and vehicle segment), the user can see the relevant impact area tabs.

Appendix B

Detailed Framework Methodology

This Appendix explains in detail the required input and calculation used to arrive at the results from the ULEV framework. The first section details the vehicle stock by age calculation; this is an important pillar calculation which is fundamental to the derivation of fuel demand and emissions. Each subsequent section focuses on the different impact areas.

Vehicle stock by age

The calculation of vehicle stock by age is a calculation which uses the sales and survival function to calculate the stock by age. Historical sales, starting in 1993, are used to build up the stock to determine the vehicle stock age in the recent history. The survival function contains a rate of survival for each age group: a new vehicle has a 99% chance and a one-year-old vehicle has a 98% chance of survival. In 1995 the stock of one-year-old vehicles is equal to 99% of new sales of 1994, and two-year-old vehicles in 1995 are equal to 98% of the stock of one-year-old vehicles in 1994. We repeat this for each age group (up to 20-year-old vehicle) and in each year until the recent history is complete. The survival function is applied, in the same way, to the projected sales from the scenario.

The benefit of this methodology is that the analytical framework can predict the composition of the stock and more accurately determine the level of emissions and fuel demand because emissions factors and fuel efficiency vary by age of vehicle.

Vehicle and infrastructure manufacturing

Vehicle and infrastructure manufacturing are represented by two parts:

- change in production costs of powertrains
- change in charging and refuelling infrastructure investment
- change in retail employment at filling stations

The supply chain effects for each element are calculated. The methodology is explained below.

Change in production costs of powertrains

The change in production costs of powertrains evaluates the loss of traditional motor vehicle manufacturing against the additional value generated from production of ULEV advanced powertrains. This is calculated by multiplying the production costs of each powertrain by the difference in sales between the scenario and baseline. The values of each powertrain are totalled to get the net effect of the change.

To calculate the supply chain effects, all vehicles using an ICE powertrain are added up (ICE and hybrid electric vehicle (HEV)) across each vehicle segment to represent traditional manufacturing. The same is done for ULEVs (plug-in hybrid electric vehicles (PHEV), battery electric vehicle (BEV) and FCEV) to represent the advanced powertrain production. These values are then multiplied by the GVA and employment effect multipliers from the Scottish Input-Output Supply and Use tables. Traditional vehicle manufacturing is proxied by the Motor Vehicle sector while advanced powertrain manufacturing is proxied by the Electrical Equipment sector.

Change in charging and refuelling infrastructure investment

The change in charging and refuelling infrastructure captures the additional cost needed, compared to the baseline, to meet the demands of ULEVs. To calculate this, a number of inputs from the assumptions are needed, including the unit costs of each charging/refuelling station as

well as a density assumption. The density assumption determines how many charging points are needed for each vehicle in the stock. A number of different charger types are considered (from e.g. wall chargers at EV owners' homes to rapid chargers for HDVs on highways). These are detailed in Appendix C along with the accompanying assumptions on costs and density.

The density assumption is applied to the stock of vehicles in a given year to calculate how many chargers are needed. Net additional chargers required are calculated by subtracting the number of chargers from the previous year to the current year. This is then added to replacement chargers. Electric chargers have an assumed lifetime of 10 years, so all chargers added in 2020, for example, need to be replaced in 2030. Hydrogen refuelling stations have an assumed lifetime of 20 years. This calculation gives the number of gross additional charges needed each year and is multiplied by the unit costs to give the total infrastructure investment. The framework assumes the cost of chargers falls by 10% for a doubling of demand, as a result of 'learning by doing' effects and economies of scale in production of chargers. There are two separate sheets: one for light duty vehicles (LDVs) and one for HDVs: 'Infrastructure costs – LDVs' and 'Infrastructure costs – HDVs'.

Supply chain effects were calculated by first splitting out the total investment required for infrastructure by the share of Gross Fixed Capital Formation of the Electricity supply sector from the UK. To capture the demand on other sectors in the economy by the investment sector, it was assumed that the building of electric charging stations and hydrogen refuelling stations would be carried out by the Electricity supply sector. Investment, now by sectors, was then multiplied by the corresponding sector's GVA and employment effect multipliers.

In the framework, we also provide an estimate of how much of the investment in infrastructure would be funded from public expenditure. The estimate is based on simple share assumptions about the proportion of how each type of infrastructure would be financed by the government. The core assumption is that government would only provide investment in publicly accessible infrastructure, thus excluding household and workplace charging. These shares are defined in "Infras. assumptions – LDVs" and "Infras. assumptions – HDVs" sheets. The split between private and government expenditure does not feed into the wider economic impacts as we do not have a detailed treatment of government budgets. We simply assume that, irrespective of the source of funding, the Scottish consumer will have to pay for the infrastructure through higher prices (in the case private investment, as firms pass costs on to consumers) or higher taxes (if government investment, as government does the same).

Change in retail employment at filling stations

The change in retail employment at filling stations captures the retail net employment effects of losing traditional filling stations and gaining rapid charging stations.

A number of assumptions are needed for this: average FTE per station (based on petrol stations and assumed to be the same for EV rapid charging stations); the number of filling stations in Scotland; ratio of filling stations per ICE vehicle; and the number of charging posts per station.

The ratio of filling stations per ICE vehicles is applied to the projected stock of ICEs to calculate the required number of Scottish filling stations in the projected period for the Baseline and the Scenario. In the next stage, the difference between the scenarios is calculated – this is the change in demand for petrol stations in the scenario. Required EV rapid charging stations is equal to the sum of LDV and HDV rapid charging posts divided by the number of charging posts per station (8). This is then subtracted from the change in demand for traditional filling stations to determine the net change in required stations. This logic is based on the simplifying assumption that additional EV rapid charging stations can and will be built at existing petrol stations. The implication is that additional EV rapid charging stations will mitigate the loss of jobs as they provide employment opportunities. Finally, the average FTE per station is applied to the net change in required stations to determine the net change in retail employment.

Consumer expenditure

The change in consumer expenditure is captured in four ways:

- fuel expenditure;
- vehicle purchase cost;
- maintenance and repair costs; and
- other consumer expenditure from change in transport costs (net change of fuel expenditure and vehicle purchase cost)

The supply chain effects for each element are also calculated. The methodology is explained below.

Change in fuel expenditure

The change in fuel expenditure captures the change in spending on different fuels from the take up of ULEVs. Fuel expenditure is equal to the price of fuel (including fuel duty and VAT) multiplied by the change in fuel demand between the baseline and the scenario. The fuel price for middle distillates, electricity and hydrogen is projected into the future based on a number of different studies. The details can be found in Appendix C.

Fuel demand is a pillar calculation. It is calculated as the average fleet fuel efficiency, multiplied by average mileage (to calculate fuel demand per vehicle per year), multiplied by the overall size of the vehicle stock (to calculate total fuel demand). Note that, in the fuel demand calculation, an additional vehicle category is added: PHEV. This has been added to calculate the electricity demand for PHEVs which is based on the assumption of the time spent in electric mode. The average fleet fuel efficiency is also a pillar calculation. It utilises the composition of vehicle stock by age and new vehicle fuel efficiency. For example, if in 2020 10% of vehicles are two-year-old vehicles and 90% are five-year-old vehicles, this means average fleet fuel efficiency is equal to 10% of 2018 new vehicle fuel efficiency plus 90% of 2015 new vehicle fuel efficiency.

Supply chain impacts are calculated by adding up the total amount of fossil fuel and ULEV fuel (electricity and hydrogen) then multiplying the change by the respective GVA and employment effect multipliers. The Coke, petroleum & petrochemical sector is used as the proxy for fossil fuels and Electricity supply sector is used for ULEV fuel.

Change in vehicle purchase costs

Change in vehicle purchase costs is broken down into two sections, primarily to avoid double counting of supply chain effects arising from production costs of the different powertrains. Firstly, the change in final purchase costs is calculated: the final purchase cost of the vehicle (including VAT and margins, assembly and distribution cost) was multiplied by the difference in sales between the baseline and the scenario. Secondly, the change in vehicle body costs is calculated (net of the powertrain costs): final purchase cost of the vehicle minus the cost of the powertrain multiplied by the change in sales between the baseline and the scenario.

The supply chain effects were based on the output generated by vehicle dealerships and vehicle body (excluding the powertrain) manufacturing. Dealership output was calculated by netting out VAT and assembly costs from changes in final purchase costs. Vehicle body manufacturing was calculated by netting out VAT and dealership margins and distribution cost. These were then multiplied by the GVA and employment effect multipliers of Wholesale & retail – vehicle sector and Motor vehicle sector, respectively, to get the supply chain effects.

Change in maintenance and repair costs

The annual maintenance and repairs costs for each vehicle are multiplied by the associated change in vehicle stock. The ICE and ULEV costs are then totalled individually. The supply

chain effects are then calculated, using multipliers from the Wholesale & retail – vehicle sector (which also includes repair of motor vehicles).

Change in other consumer expenditure from change in transport costs

The final step to calculate the change in consumer expenditure involved adding up the change in fuel expenditure, change in vehicle purchase costs (including VAT and margins, assembly and distribution cost), maintenance costs and infrastructure costs for all vehicle segments. However, unlike passenger cars, the change in other consumer expenditure from changing costs/savings in the haulage and public transport segment (Vans, HDV and Buses) depends primarily on the competitiveness of the market. A highly competitive market will mean the haulage sector will have to absorb the costs to maintain its market share. A lack of competition means it can increase costs to consumers without damaging market share. As there is little known on this market in Scotland, the user can decide which pass-through rate to implement: whether all the savings/costs are passed on (100%), no savings/costs are passed on (0%), and all values between (0-100%). Once a value is determined by the user, the net purchases are added up across all sectors; the signs are inversed so that a positive number represents an overall saving which it is assumed is spent elsewhere in the economy. A negative number represents additional spending on transport costs which will reduce consumer expenditure in other areas.

The total transport cost was shared out among the different industries in the economy, based on the composition of final consumer expenditure of households in each industry. The share of spending in each industry was then multiplied by the corresponding GVA and employment effect multipliers of each industry, then all totalled to get the total supply chain effect of the change in other consumer expenditure from the change in transport costs.

Impact on CO₂ emissions and air quality

The impact of emissions is broken down into three sections:

- CO₂ emissions and air quality;
- health impacts; and
- social cost of carbon

Change in CO₂ emissions and air quality

Due to the input data of emission factors there are some slight differences between the calculation of CO₂ emissions and the other pollutants. Emission factors for CO₂ are measured in terms of fuel burnt (kg CO₂/kg of fuel). Thus, the calculation for the change in CO₂ emissions is simply the CO₂ emission factor multiplied by the change in fuel demand between the scenarios. This is known as the Tier 1 methodology outlined in the EMEP/EEA air pollutant emissions inventory guidebook 2016 (EEA, 2018).

The calculation of NO_x and PM_{2.5} follows the Tier 2 methodology, given by the same source (EEA, 2018). It is vehicle stock multiplied by the average mileage, multiplied by the emission factors. Emission factors are given per kilometre driven. A more nuanced approach is used to make full use of the vehicle stock by age, with vehicle age multiplied by the corresponding emission factor. For example, a five-year-old vehicle in 2020 is multiplied by the emission factor from 2015. These are pillar calculations which can be found on sheet 'NO_x emission calculation' and 'PM_{2.5} emission calculation' in the framework.

Change in health impacts

The emission of local air pollutants is known to have adverse effects on human health; as such, the change in health impacts is proxied by the damage cost. These damage coefficients for NO_x and PM_{2.5} are simply multiplied by the change in respective emissions calculated above to derive the total impact on health from local air pollutants.

Reduction in social cost of carbon

To monetise the impact of CO₂ emissions, we estimate their social costs. The reduction in the social costs of carbon is estimated by multiplying the social cost of carbon (per tonne), as reported in the UK government Green Book, by the total reduction in CO₂ emissions.

Change in Fuel supply

Here the impact of changes in fuel supply in response to the deployment of ULEVs is calculated. It is broken into two parts:

- oil production supply chain; and
- additional electricity and hydrogen demand

Change in oil production supply chain

First, the reduction in fossil fuel expenditure is taken from the 'Consumer Expenditure' tab. This is then shared out based on the composition of Coke, petroleum and petrochemicals sectors intermediate consumption to determine the amount this sector will no longer purchase (due to a reduction) from Oil and gas extraction – Oil and gas extraction is used a proxy for oil supply. This value is then split into domestic and imported oil by using the share of domestic content (total domestic use divided by total intermediate use (including imports)) of the Oil and gas extraction sector from the Scottish Input-output supply and use tables.

Additional electricity and hydrogen demand

The additional electricity and hydrogen demand is a simple calculation. It involves adding up the fuel use by the relevant ULEVs from the 'Fuel demand' tab: BEVs and PHEVs across all vehicle segments for additional electricity demand and FCEVs across all vehicle segments for additional hydrogen demand.

Change in government revenues

The change in government revenues calculates the associated government tax revenue from the deployment of ULEVs. The change in revenue from three different taxes are calculated:

- fuel duty;
- VAT; and
- corporation tax

Change in fuel duty

The change in fuel duty is calculated by multiplying the fuel duty by the difference in fuel demand between the two scenarios.

Change in VAT

The change in VAT is the sum of fuel expenditure and vehicle purchase costs (from the 'Consumer Expenditure' tab) multiplied by the VAT rate in Scotland. The VAT from change in consumer expenditure (spending elsewhere in the economy) is also included here.

Change in corporation tax

The change in corporation tax is more complicated to calculate because it involves determining the profit generated in the economy from the transition. To work out the profit (Gross operating surplus) an industry-wide share of profits (Gross operating surplus divided by GVA) was calculated and applied to the sum of the GVA of all impact areas and the change in oil supply. The corporate tax rate was then applied to this sum.

Balancing Fuel duty

We assume that, in the long term, the erosion of fuel duty will be compensated by an equivalent taxation on road users to prevent a rebound in travel demand. In this framework we do not assess a specific form of road taxation. Instead, we take the total fuel duty lost relative to baseline and subtract it from any net savings in consumer expenditure.

Appendix C

Data Sources

This section outlines each input assumption, the corresponding source and, where necessary, the methods taken to construct the input assumptions from multiple sources. The different input assumptions can be broadly categorised into three separate sections:

- vehicle and infrastructure parameters;
- economic parameters; and
- emission parameters.

Vehicle and infrastructure characteristics

For passenger cars a medium-sized vehicle is assumed; for vans a vehicle between 3.5t and 7.5t is assumed; and for HDVs a 40t articulated freight truck is considered.

Historical stock and sales

Historical stock and sales are sourced from Scottish Transport Statistics No 37 2018 Edition (Transport Scotland, 2018). Data is available from 1993 to 2017. However, stock and sales are only available by type of vehicle, body type (vehicle segment) or method of propulsion (fuel type/powertrain). To get stock and sales by vehicle segment and powertrain, shares of powertrain were generated and applied to the different vehicle segments. This method assumes that each vehicle segment has the same split of powertrains. An exception was made for HDVs where it was assumed that all vehicles were diesel.

Vehicle assumptions

Vehicle assumptions include the total cost of the vehicle (€, 2015), the powertrain cost (€, 2015), the margins, assembly and distribution cost assumptions (%), the VAT rate (%) and the euro/pound exchange rate.

The total cost of the vehicle excluding margins and VAT for ICEs passenger cars, vans and HDVs is obtained from two different sources. Element Energy ECCo Model V2.14.0 attribute data - baseline scenario for passenger cars and vans, and Trucking into a Greener Future (Cambridge Econometrics, 2018) for HDVs. Data is also collected for the total costs of other powertrains, but apart from vans (see next paragraph) they are not used.

Powertrain costs for passenger cars come from the report Cost and Performance of EV Batteries conducted by Element Energy for the Committee on Climate Change (Element Energy, 2012). FCEV powertrain costs are Cambridge Econometrics' own calculations based on applying the cost differential of medium and large ICE vehicles to BEVs. Powertrain costs for vans were not available; these were estimated by applying the ratio between the total cost of a van and a passenger car to the powertrain cost of a passenger car. Powertrain costs for HDVs were obtained from the Heavy Duty Vehicle Technology Potential and Cost Study for ICCT (Ricardo-AEA, 2017). Powertrain cost data is available up to 2050, in five-year intervals.

Margins, assembly and distribution cost (%) assumptions were sourced A portfolio of powertrains for Europe: a fact-based analysis (McKinsey, 2015).

The VAT rate (20%) is from HMRC and euro/pound exchange rate from Eurostat.

Vehicle final and production costs

Powertrain costs (in £, 2015) are calculated by converting euro values to pounds by applying the exchange rate. Linear interpolation is used to calculate the cost at one-year intervals – it is

assumed that powertrain costs change by the same absolute value each year between the published data points, so the change happens at a constant rate (in absolute terms).

Final new vehicle prices including margins and VAT (£, 2015) are calculated for ICE passenger cars, ICE vans and ICE HDVs by applying the margins, VAT rate and exchange rate to the total costs of vehicles. The final costs of the other powertrains are calculated by netting out the cost of the engine from the final cost of ICEs and then adding the powertrain cost. For HEV and PHEV, the additional cost is added on top of the existing ICE.

Vehicle maintenance and repair costs

Vehicle maintenance and repair costs are supplied by Element Energy. Maintenance costs for passenger car and vans are from their in-house model ECCo Model V2.14.0 attribute data - baseline scenario. HDV and Bus data are from Element Energy's work for the Connected Places Catapult (2019) H2SM Vehicle Cost Benefit Model v3.03.

Electric charging infrastructure assumptions

Infrastructure density assumptions were sourced from Element Energy's work for Fuelling Europe's Future (Cambridge Econometrics, 2018). The table below indicates the number of EVs per charging point. The coverage column indicates which vehicle segment the charger is for. This is important because different size chargers are required to meet the varying battery sizes of the different vehicle segments. Note that these values are constant over the projected period; there is scope to alter the density assumption if new data is available.

	Coverage	EVs per charging point
Household charging	Passenger cars	1.25
Work charging	Passenger cars and vans	5
Public charging	Passenger cars and vans	5
Depot Van	Vans	1
Rapid charging (highways)	Passenger cars and vans	300
Depot BEV	HDVs (BEV only)	1
Depot PHEV	HDVs (PHEV only)	1
Rapid charging (highways)	HDVs	28

Table 1 Infrastructure density assumptions for LDVs and HDVs

LDVs costs are from the same source as the density assumptions. Additional calculation for the installation of household charging is made based on the proportion of people living in flats and

houses in Scotland²¹. It is assumed that installing a household charger at a block of flats (£726) will be more expensive than at a private household (£290).

	Power (kW)	Charger time – 25kWh battery (approx.)	Production costs (£)	Installation cost (£)
Household charging	3 – 7	2 – 8 hours	436	347
Work charging and Depot Van	7	4 – 8 hours	581	290
Public charging	11	2.5 hours	1815	290
Rapid charging (highways)	50	30 minutes	21,775	80,245*

Notes: * includes grid connection, and other costs for greenfield and brownfield sites.

Table 2: Infrastructure cost assumptions - LDVs

Installation costs of rapid charging (on highways) are much higher because they include additional costs for preparing the site (e.g. grid connection). There are two types of sites: greenfield and brownfield. Brownfield sites are existing stations which only require additional grid connections and civil engineering. Greenfield sites are brand new and therefore more expensive. The expense also includes grid connections and civils costs as well as additional costs for building access roads, site works and professional fees. The ratio of brownfield to greenfield sites is 6:1, based on the analysis in Clean Power Transport Infrastructure Deployment which calculates the number of charging points required to reach full mobility on the nine TEN-T corridors (European Commission, 2017). This report also provides the relevant cost data.

Cost data for HDV is presented in the table below; the costs are based on a linear scale-up of the cost data used for LDVs. This was originally done for the report Trucking into a Greener Future (Cambridge Econometrics 2018). All rapid chargers (for highways) for HDVs are assumed to be greenfield sites. Depot chargers are intended to be overnight chargers.

	Power (kW)	Charger time – 1000kWh battery (approx.)	Charge time- 625kWh (sufficient for avg. trip)	Production costs (£)
Depot BEV	90	7 hours	4 hours	26,130
Depot PHEV	22			1,815

²¹ Scottish house condition survey 2016: key findings (2017). Housing and Social Justice Directorate. Accessed on 19/09/19 here: <https://www.gov.scot/publications/scottish-house-condition-survey-2016-key-findings/pages/4/>

Rapid charging (highways)	700	1.43 hours	56 minutes	348,403
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Notes: * includes grid connection, and other costs for greenfield and brownfield sites.

Table 3: Infrastructure cost assumptions - HDVs

HRS infrastructure assumptions

HRS infrastructure density assumptions (FCEVs per HRS) for LDVs (50-500kg/day) are based on The Italian hydrogen mobility scenario implementing the European directive on alternative fuels infrastructure (DAFI 2014/94/EU) (Viesi, Crema and Testi, 2017). Density assumptions for HDVs (10000 and 25000kg/day) are from Trucking into a Greener Future (Cambridge Econometrics, 2018)/

	2020	2030	2040	2050
LDV - 200kg/day	99	127	142	153
LDV - 500kg/day	198	254	284	305
LDV - 1000kg/day	990	1272	1421	1526
HDV - 10000kg/day	137	260	286	286
HDV - 25000kg/day	476	714	714	714

Table 4: HRS infrastructure density assumptions

The costs calculations for HRS infrastructure are derived from Element Energy's work for Fuelling Europe's Future (Cambridge Econometrics, 2017), they consider important details about the stations and how hydrogen will be produced. HRS infrastructure includes a dispenser and a storage and compression unit. For more information, the user is referred to the original technical report.

HDV HRS infrastructure is sourced from literature on bus refuelling infrastructure (NewBusFuel, 2017) which covers bus refuelling infrastructure up to 5000kg. However, for HDVs, larger values are expected so we scaled up the costs using the power ratio of 0.6 to derive the sums needed for the larger stations. A summary of the unit costs (£, 2015) is available in Table 4.5 below.

	2020	2030	2040	2050
LDV - 200kg/day	725,840	508,088	725,840	508,088
LDV - 500kg/day	943,592	725,840	943,592	725,840
LDV - 1000kg/day	1,451,680	1,088,760	1,451,680	1,088,760

HDV - 10000kg/day	19,170,911	19,170,911	19,170,911	19,170,911
HDV - 25000/kg/day	32,316,246	32,316,246	32,316,246	32,316,246

Table 5: HRS capital costs (£, 2015)

Petrol station assumptions

There are several assumptions for petrol stations: the number of historical filling stations in Scotland; ratio of filling stations per ICE vehicle; average FTE per station; and number of charging posts per station.

Historical filling stations in Scotland are based on the number of petrol stations in the UK which was sourced from Statistical Review 17th Edition (UKPIA, 2019). Filling stations were allocated to Scotland based on the proportion of Scottish ICE fleet of the total UK ICE fleet (Department for Transport, 2019). A limitation of this methodology is that it is assumed the Scottish petrol stations have the same density assumptions as UK petrol stations.

The ratio of filling stations per ICE is based on UK data: the total number of filling stations (as above) divided by the total number of ICEs in the UK (as above).

Average FTE per station is based on the Study of Petrol Stations in Rural Scotland (The Scottish Office Central Research Unit, 1998). It estimates that, on average, there are 3.5 full-time staff and 3.1 part-time staff. The average FTE per station (4.9) is derived by converting the number of part-time staff to FTE (1.4), then adding to the average full-time staff. FTE for part-time staff is based on real data from the Office for National Statistics. Average actual weekly hours of work for part-time workers in 2019 were 16.3 hours which amounts to 47% of a full-time week (16.3/37.5); 47% of 3.1 part-time staff is 1.4 FTE.

Number of charging posts per station is assumed to be 8.

Vehicle mileage

Average annual vehicle mileage (km) is calculated by dividing the total travel demand (millions of vehicle-km) by historical stock numbers (millions of vehicles). Travel demand is from Scottish Transport Statistics No 36 2017 Edition (Transport Scotland, 2018) and is broken down by vehicle segments for which the latest year available is 2016. The calculated annual average mileage in 2016 is held constant for the projected period.

New vehicle fuel efficiency

New vehicle fuel efficiency by vehicle segment and powertrain presents the real-world efficiency of new vehicles. The table below indicates which sources were used for each vehicle segment and powertrain.

Powertrain	Vehicle segment	Source
ICE	Passenger Car	Element Energy
HEV	Passenger Car	Element Energy
PHEV	Passenger Car	ICCT pocketbook (2019) and Fueling Italy's Future (ECF, 2018)
PHEV (elec)	Passenger Car	ICCT pocketbook (2019) and Fueling Italy's Future (ECF, 2018)
BEV	Passenger Car	ICCT pocketbook (2019) and Fueling Italy's Future (ECF, 2018)
FCEV	Passenger Car	Element Energy
ICE	Vans	Element Energy
HEV	Vans	Element Energy
PHEV	Vans	Element Energy
PHEV (elec)	Vans	Element Energy
BEV	Vans	Element Energy
FCEV	Vans	Element Energy
ICE	HDV	HDV white paper (ICCT, 2017) and Department for Transport
HEV	HDV	HDV white paper (ICCT, 2017) and Department for Transport
PHEV	HDV	HDV white paper (ICCT, 2017) and Department for Transport
PHEV (elec)	HDV	HDV white paper (ICCT, 2017) and Department for Transport
BEV	HDV	HDV white paper (ICCT, 2017) and Department for Transport
FCEV	HDV	HDV white paper (ICCT, 2017) and Department for Transport

Table 6: Sources of New vehicle fuel efficiency

Data from Element Energy is taken from its in-house model ECCo Model V2.14.0 attribute data - baseline scenario. Data from the ICCT pocketbook (ICCT, 2019) and Fuelling Italy's Future (Cambridge Econometrics, 2018) is constructed by adjusting Italian new vehicle fuel efficiency to UK new vehicle fuel efficiency; data from Fuelling Italy's Future is divided by the average fuel efficiency of a new Italian ICE, then multiplied by the average fuel efficiency of a new UK ICE (ICCT pocketbook). New vehicle fuel efficiency of HDVs is taken from the ICCT's White Paper on HDVs (ICCT, 2017) and back casted based on real world data from the Department for Transport.

Note new vehicle efficiency for PHEV Vans is set equal to ICE Vans and PHEV (elec) Vans is set equal to BEV Vans. This is due to the variation in treatment between Element Energy's model and the ULEV framework. New vehicle efficiency in EE's model already includes time spent in electric mode whereas in the ULEV framework this part is calculated later on.

PHEV time spent in electric mode

The time spent in electric mode assumptions are used to calculate fossil fuel and electricity demand of PHEVs. PHEV time spend in electric mode for LDVs is from figure 34 in a report for the WWF UK: Electric vehicles in the UK and Republic of Ireland (Element Energy, 2010). The time spent in electric mode for LDVs increases over time. Time spent in electric mode for HDVs was based on Cambridge Econometric's own assumptions for Trucking into a Green Future (Cambridge Econometrics, 2018). The assumption utilises data from TRACCs to determine the average trip length and amount the assumed battery could meet. The assumption for HDVs is time invariant.

Petrol and diesel share

The share of petrol and diesel vehicles is used to help estimate the emission coefficients for ICEs. It is calculated from the same source as historical stock data: Scottish Transport Statistics No 37 2018 Edition (Transport Scotland, 2018).

Economic parameters

Scottish Input-Output supply and use tables

Scottish Input-Output tables are sourced from Scottish Government statistics (Scottish Government Statistics, 2018). They provide assumptions on the Type I and Type II GVA and employment effect multipliers, share of household expenditure on industries (%), share of intermediate consumption of the Coke, petroleum and petrochemicals industry and the domestic content share of Oil and gas extraction.

UK Input-output supply and use tables

The UK tables are collected due to a lack of Gross Capital Fixed Formation in the Scottish tables. The Gross Capital Fixed Formation is investment into physical capital by each industry; it is used to determine where the investment demand of infrastructure goes. The UK tables are from the ONS (ONS, 2019).

Fuel prices

Historical prices for petrol and diesel are collected from the Oil Price Weekly Bulletin, excluding fuel duty and VAT. Data is not available for Scotland so data from UK is used as a proxy. This is then grown in line with the oil price projections from the different scenarios from the IEA World Energy Outlook (IEA, 2018). The scenarios from the IEA are only available to 2040. To estimate the price in the final 10 years, the average growth rate from the last 5 years is projected forward. Finally, fuel duty and VAT are then included in the fuel price.

Electricity price data is from Eurostat. However, two different prices were obtained:

- wholesale prices for HDVs (band IE); and
- residential prices for LDVs (band DC).

The categories are determined by the total annual demand for electricity. Historical electricity prices exclude VAT and other taxes/levies. Both sets of prices are projected forward based on final electricity price from EU Reference Scenario (European Commission, 2016). Before use in the framework, the fuel duty and taxes are included.

Hydrogen prices are based on Element Energy's work for Fuelling Europe's Future (Cambridge Econometrics, 2018) using a number of sources: UK TINA, FCH JU Electrolyser study and data from H2Mobility initiatives.

Taxation

Fuel duty for the UK and Scotland is sourced from the Office for Budget Responsibility²². VAT and corporation tax are from HMRC.

Emission parameters

Emissions factors

Emission factors are from the EMEP/EEA air pollutant emissions inventory guidebook 2016 (European Environment Agency, 2018). Tier 1 emission factors are used for CO₂ and Tier 2 for NO_x and PM_{2.5}. To estimate the weighted average emission factor for ICEs (comprising of petrol and diesel vehicles), data on the share of petrol and diesel vehicles was applied to the respective emission factors.

Damage coefficients

Damage coefficients are from Defra (Ricardo, 2019). Damage coefficients specific to road transport were used. However, the impacts of pollution on productivity were netted out. This was done to obtain damage coefficients which only represent health problems. The share of productivity was netted out from the coefficient by first calculating the share of productivity damage in the industry wide damage coefficients and then applying it to the road transport specific damage coefficient.

Social cost of carbon

The social cost of carbon (£/tonne) is sourced from the Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions appraisal (Department for Business, Energy & Industrial Strategy, 2019). The social cost of carbon is given in 2018 prices; the GDP deflator provided for the Green Book was used to convert this to constant 2015 prices.

²² Fuel duties. Office for Budget Responsibility. Accessed on 01/10/19 here: <https://obr.uk/forecasts-in-depth/tax-by-tax-spend-by-spend/fuel-duties/>

Appendix D

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